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(54) Method of Making Optical Fibres

(57) A method of making an optical fibre, in which method an optical fibre preform P is heated in a furnace 5 so as to melt one end of the preform P. A fibre F is drawn from the molten end of the preform P and is withdrawn from the furnace 5, the portions of the preform P and fibre F which are located inside the furnace are enveloped in an inert gas stream which enters the furnace 5 through a supply duct 49. The drawn fibre F is cooled, provided with a coating of a synthetic resin in a coating device 9, and the coated fibre is wound onto a reel 15. A problem in such a method arises from contaminants which settle on the fibre F in the furnace 5. An overpressure of the inert gas is maintained inside the furnace 5, and a stream of gas enveloping the fibre F passes from the inside of the furnace to the outside of the furnace through a condenser element 61.

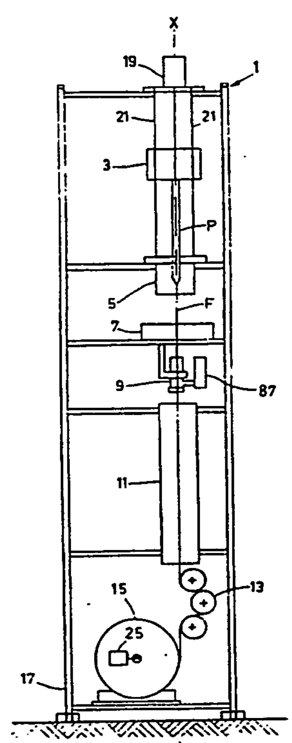

FIG.1

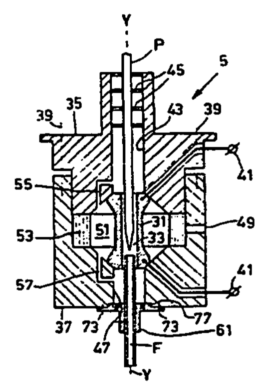

FIG.2

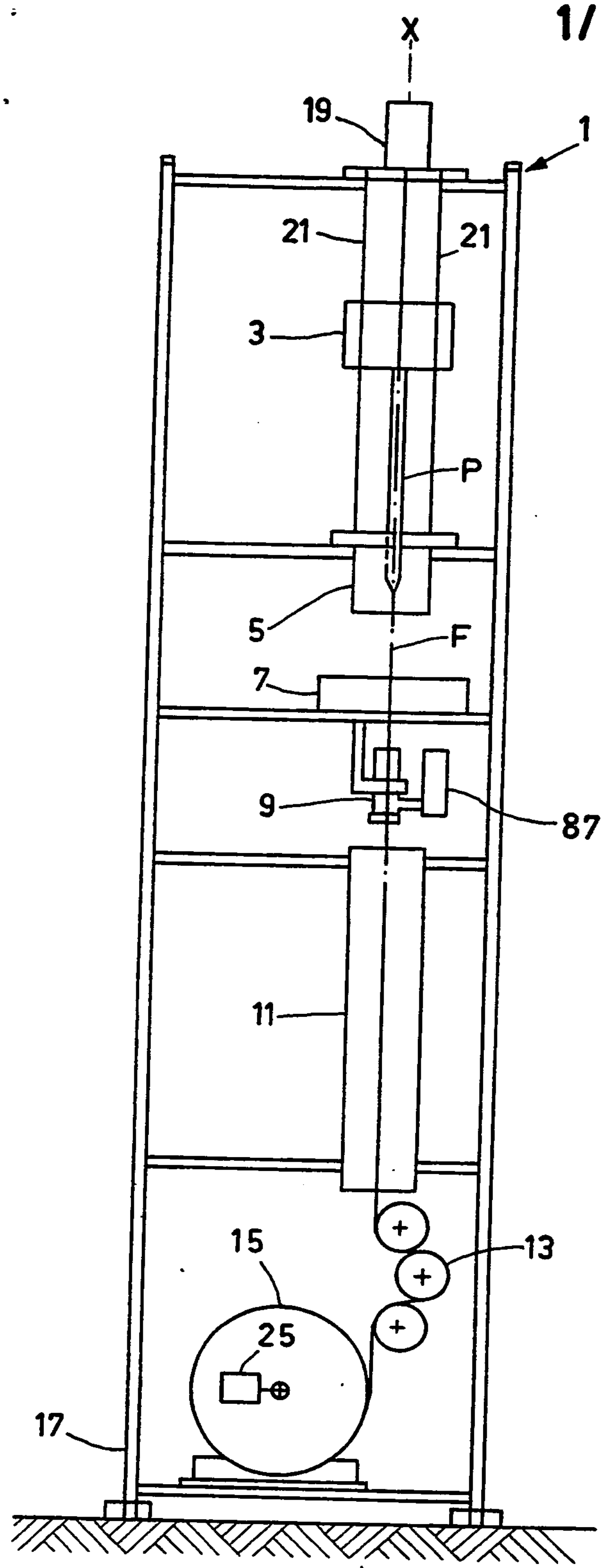

FIG.1

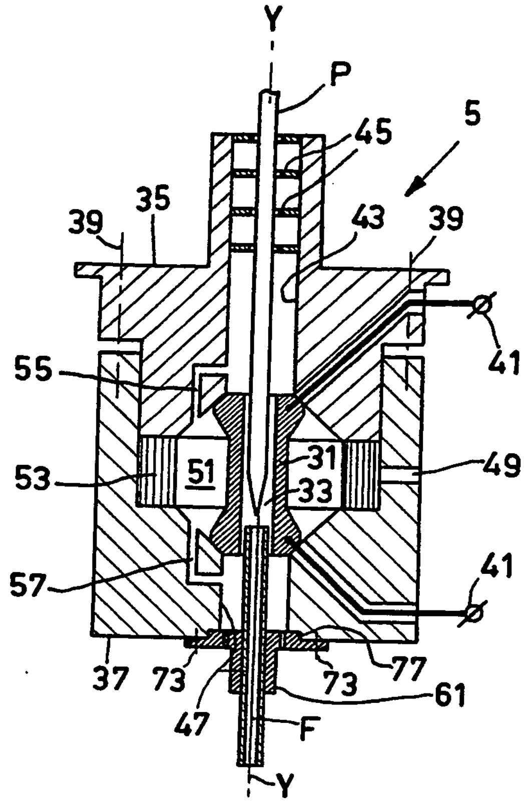

FIG.2

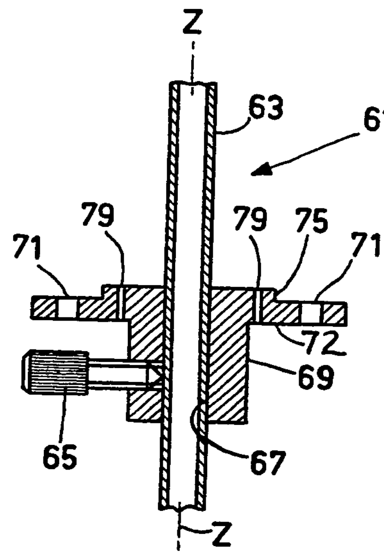

FIG.3

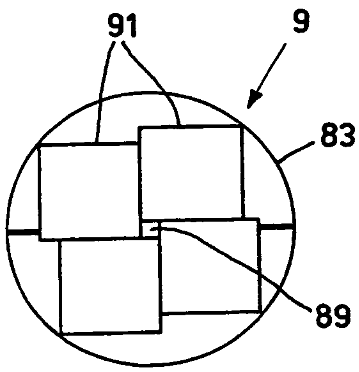

FIG.4a

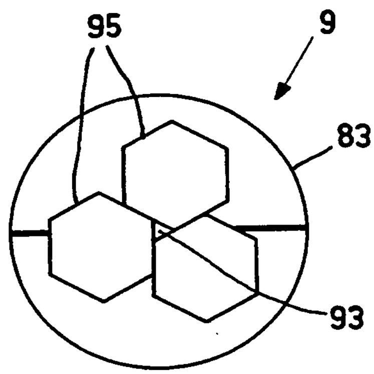

FIG.5a

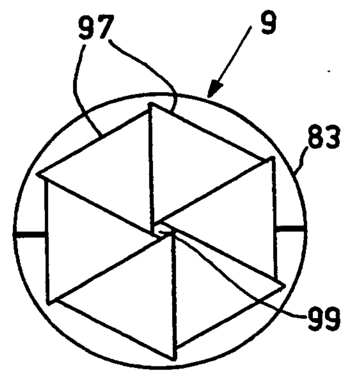

FIG.6a

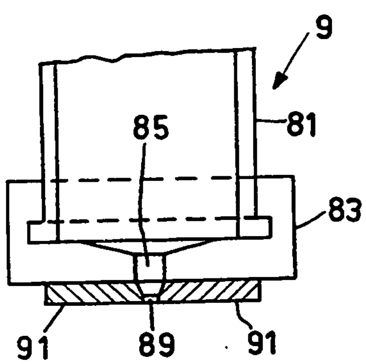

FIG.4b

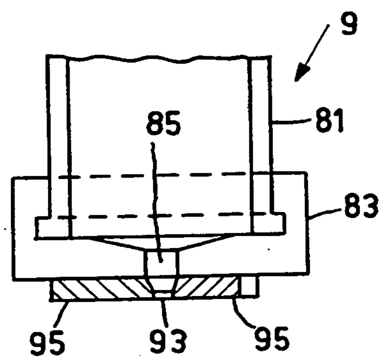

FIG.5b

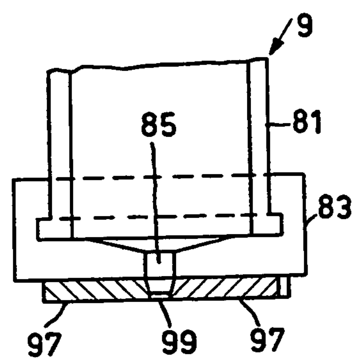

FIG.6b

SPECIFICATION

Method and Apparatus f r Manufacturing Optical Fibres

The invention relates to a method of manufacturing optical fibres, an optical fibre preform being heated in a furnace so as to melt one end of the preform, a fibre being drawn from the molten end of the preform and withdrawn from the furnace, the portions of the preform and of the fibre located in the furnace being flushed with a gas, after which the drawn fibre is cooled and provided with a coating which is subsequently dried, and finally the fibre thus obtained is wound onto a reel.

Such a mehod is known from the article "Preform Fabrication and Fiber Drawing by Western Electric Product Engineering Control Center", published in "The Bell System Technical Journal", Vol. 57, No. 6, July—August 1978, pages 1735 to 1744.

The preform is heated in this known method by means of a graphite resistance-element. Owing to its thermal and mechanical properties, *i.e.* a high thermal shock resistance and a suitable strength at high temperatures, graphite is extremely suitable for this purpose; moreover, graphite is comparatively cheap, is available in a pure form and is easy to work. However, graphite has the drawback that at the operating temperatures of approximately 2000°C, it is subject to substantial oxidation. It is known that the drawing conditions may adversely affect the strength of the drawn fibre. Contamination of the fibre by dust particles as a result of the deposition of reaction products (which have been formed, for example, by reactions between components of the furnace and the atmosphere inside the furnace) such as silicon carbide or silica particles will damage and impair the properties of the fibre. Contamination of the fibre by dust particles can be avoided by drawing the fibre in a dust-free environment. The formation of reaction products can be limited by maintaining an overpressure of an inert gas atmosphere in the furnace, so that the entry of air into the furnace is prevented. Settlement of reaction products on the fibre can be minimized by surrounding the fibre with an inert gas stream.

It is the object of the invention to provide a method which results in a quality improvement and an increased tensile strength of the optical fibre manufactured by this method compared with optical fibres made by prior art methods.

The invention provides a method of manufacturing an optical fibre, comprising the steps of heating an optical fibre preform in a furnace so as to melt one end of the preform, drawing an optical fibre from the molten end of the preform, withdrawing the optical fibre from the furnac , enveloping the portions of the preform and the optical fibre which are within the furnace in an inert gas stream, cooling the optical fibre, coating the optical fibre with a layer of synthetic resin and winding the coated optical fibre onto a reel, wherein the gas stream enveloping the optical fibre passes from the inside of the furnace to the outide of the furnace through a condenser element which surrounds the optical fibre, and wherein an overpressure of the inert gas is maintained inside the furnace with respect to the pressure outside the furnace. The optical fibre may be coated, for example, by extrusion melting, melting a finely-divided powder, coating with a liquid synthetic resin which is subsequently cured, or with a layer of suspension or a soluti n of a synthetic resin.

An optical fibre may be manufactured by a method according to the invention comprising the steps of heating an optical fibre preform in a furnace so as to melt one end of the preform, drawing an optical fibre from the molten end of the preform, withdrawing the optical fibre from the furnace, enveloping the portions of the preform and of the optical fibre which are within the furnace in an inert gas stream, cooling the optical fibre, coating the optical fibre with a lacquer, drying the coated optical fibre, and winding the dried coated optical fibre onto a reel, wherein the gas stream enveloping the optical fibre passes from the inside of the furnace through a condenser element which surrounds the optical fibre, and wherein an overpressure of the inert gas is maintained inside the furnace with respect to the pressure outside the furnace.

The condenser functions as a cold spot, so that gaseous reaction products settle on the condenser and the optical fibre itself is not contaminated by condensed reaction products.

Comparative measurements have revealed that optical fibres manufactured by a method according to the invention have a greater tensile strength than optical fibres manufactured by prior-art methods.

The invention also relates to apparatus suitable for performing a method according to the invention, which apparatus comprises a holder for an optical fibre preform, a furnace, a coating device, a drying device, a drawing device and a winding device, the furnace comprising a graphite resistance-element bounding a central heating chamber, the furnace having an inlet bore containing sealing means, an exit bore, and a supply duct for the supply of a gas is characterized in that the furnace is provided with a tubular condenser which is arranged in the exit bore, the centre lines of the condenser and of the heating chamber coincide, one end of the condenser is located inside the heating chamber and the other end is disposed outside the furnace. The tubular condenser has a hot end and a relatively cool end, there being a substantial temperature drop along the length of the condenser. Owing to the comparatively great length of the condenser, the optical fibre drawn from the optical fibre preform is surrounded and protected by the condenser over practically the entire cooling path, which condenser contains a gas stream which envelops the optical fibre being drawn.

One embodiment of an apparatus suitable for

performing a method according to the invention is characterized in that the condenser is secured in a central bore of a substantially cylindrical support, which support fits into the exit tube of the furnace and is provided with a plurality of outlet ducts, through which ducts gas can pass from inside the furnace to outside the furnace. The support serves for the correct positioning of the condenser element and for the partial closure of the exit bore of the furnace chamber. The inert gas fed through the supply duct flows out of the furnace partly along the preform through the sealing means and out of the inlet bore, partly through the condenser along the fibre being drawn and partly through the outlet ducts. A sufficiently high flow-rate of the inert gas is used so that with a given condenser, a given sealing means in the inlet bore and given outlet ducts, an overpressure of inert gas is maintained in the furnace with respect to the pressure outside the furnace.

In another embodiment of the apparatus suitable for performing a method according to the invention, the condenser is made of quartz glass. The colour of the end of the quartz-glass condenser which is outside the furnace, is an indication of the temperature as well as of the correct location of the hot end of the preform in the heating chamber. Furthermore it appeared that with a quartz glass condenser, the reaction products can be condensed satisfactorily.

In a further embodiment of the apparatus suitable for performing a method according to the invention, the condenser is made of platinum. Platinum has a higher thermal resistance (that is to say it can withstand higher temperatures) than quartz glass and a much higher coefficient of thermal conductivity than quartz glass and the end in the heating chamber may be arranged nearer the melting zone so that a better protection of the drawn fibre is obtained.

After the optical fibre has been drawn from the furnace and after cooling, the fibre should be protected as soon as possible against contamination, ageing and mechanical damage. For this purpose the fibre is provided with a hard coating of a synthetic resin having a thickness of for example 3 to 5 μm for a fibre having a diameter of 100 μm. The coating is applied using a low-viscosity quick-drying lacquer with the aid of a coating device which comprises a reservoir, provided with a nozzle opening, but mechanical guiding and centring of the fibre cannot be used in view of the risk of damage to the coating. Hitherto a reservoir was used for this coating process having a circular nozzle opening. However, when such a nozzle opening is used, the centring effect of the coating stream on the fibre is very small. The fibre tends to pass through the nozzle opening with such a high eccentricity that owing to surface tension the coating is not formed uniformly and concentrically over the fibre circumference of the fibre. This gives rise to bending stresses in the fibre during drying of the coating, resulting in microbending (deformations of the fibre of the order of μm).

A uniform and concentric coating is obtained in another embodiment of an apparatus suitable f r performing a method according to the invention, in which apparatus the nozzle opening is polygonal. Owing to the hydraulic pressures exerted in the corners of the nozzle opening, the coating will exert a directional centring effect on the fibre As the coating is applied in a plurality of thicker and thinner strips which are uniformly distributed over the fibre circumference, the coating is distributed concentrically over the circumference of the fibre under the influence of the surface tension of the centring liquid. Owing to the uniformly distributed strips, an improved lubricating effect is obtained.

A further embodiment of an apparatus suitable for performing a method according to th invention is characterized in that the nozzle opening is bounded by a plurality of adjustable segments. By adjusting the locations of the segments, it is possible in a simple manner to adapt the nozzle opening to the fibre diameter and to adjust the desired coating thickness, in such a way that mechanical contact of the fibre with the nozzle wall is avoided.

Some embodiments of the invention will now be described with reference to the drawings, in which:—

Figure 1 schematically shows a side elevation of an apparatus according to the invention for manufacturing optical fibres,

Figure 2 is a schematic longitudinal section of the furnace of Figure 1 shown on an enlarged scale,

Figure 3 shows a detail on an enlarged scale of the furnace shown in Figure 2,

Figures 4a, 5a and 6a are bottom plan views of different embodiments of the coating device which is schematically shown in Figure 1, and

Figures 4b, 5b and 6b are side-sectional elevations of the bottom parts of the coating devices shown in Figures 4a, 5a and 6a respectively.

The apparatus 1 shown in Figure 1 for manufacturing optical fibres comprises a holder 3 for a preform P, a furnace 5 for melting and end of the preform P from which a fibre F is drawn, a measuring device 7, a coating device 9, a drying device 11, a drawing force measuring device 13 and a reel 15. These components and devices are mounted on a common frame 17, the centre lines of the furnace 5, the measuring device 7 and the coating device 9 coinciding with a common axis X—X. The holder 3 is moved in a manner, known *per se*, by a drive mechanism 19 on guides 21. The reel 15 is driven by a motor 25 and this combination of reel 15 and motor 25 serves as drawing device. The measuring device 7 is used to monitor the diameter of the fibre F.

Figure 2 shows the furnace 5 on an enlarged scale. This furnace 5 has a substantially tubular, interchangeable, graphite heating element 31 comprising central cylindrical heating chamber 33, which element 31 is secured between two housing sections 35 and 37, these sections 35

and 37 being interconnected by screw connections 39. The heating element 31 is heated by direct current passage and for this purpose it is connected to terminals 41 which can be connected to a power supply source, not shown. The housing section 35 is formed with an inlet bore 43 through which the preform P is fed into the heating chamber 33, sealing partitions 45 being disposed in this bore 43. The housing section 37 is formed with an exit bore 47 and a supply duct 49 through which an inert gas, preferably argon is supplied. The supply duct 49 debouches into an annular gas chamber 51, which surrounds the heating element 31, an annular heat-insulating filter 53 consisting of zirconium dioxide abutting the circumferential wall of said chamber 51. The gas chamber 51 communicates with the inlet bore 43 *via* gas ducts 55 in the housing section 35 and with the exit bore 47 *via* gas ducts 57 in the housing section 37. A condenser element 61 (shown on an enlarged scale in Figure 3) extends into the exit bore 47.

The condenser element 61 comprises a tube 63 of a high-melting pure material, such as quartz glass or platinum, which tube 63 is adjustably secured by means of a clamping screw 65 in a bore 67 of a cylindrical support 69 integrally formed with a flanged portion 72. The support 69 is formed with holes 71 in the flanged portion 72 whereby the element is secured to the housing section 37 by means of screw connections 73. By means a centering flange 75 on the flanged portion 72 of the support 69 and a co-operating centring rim 77 on the housing section 37, the support 69 is centred in such a way that the longitudinal axis Z—Z of the tube 63 coincides with the longitudinal axis Y—Y of the heating chamber 33. A plurality of outlets ducts 79 extend through the thicker part of the flanged portion 72 and are regularly spaced around the circumference. The tube 63 has an outer diameter smaller than the diameter of the heating chamber 33 and is positioned in such a way in the axial direction that one end is located in the heating chamber 33 near the melting zone and the other end is outside the furnace 5. The housing sections 35 and 37, in a manner known *per se*, are provided with cooling chambers and cooling ducts, not shown, and are preferably made of a material having a high coefficient of thermal conduction, such as copper or aluminium.

In order to manufacture optical fibres, an optical fibre preform P consisting of a quartz-glass rod or of a composite rod comprising a core and quartz-glass cladding is secured in the holder 3 in such a way that the axis of the preform P coincid s with th axis X—X of the apparatus 1. The preform P is longitudinally positioned in such a way that the lower end is disposed in the melting zone of the furnace 5. As a result of the heating in the furnace 5 the lower end of the preform P begins to melt, while simultaneously an optical fibre F is formed, which is passed through the measuring device 7, is threaded through the coating device 9, is passed through the drying device 11, is passed over the drawing-force measuring device 13 and is finally secured to the reel 15. After this the process can proceed continuously, the preform P being f d in at a constant speed by the drive mechanism 19, the fibre F being drawn at a constant drawing speed by the reel 15.

Contamination of the fibre F by settling of reaction products formed in the furnace 5 is minimized by using a method according to the invention by the condenser element 61 shown in Figures 2 and 3, which functions as a cold spot and as a trap for contaminants, and which retains the condensable reaction products, so as to prevent such reaction products from settling on the optical fibre F. Argon is supplied through the duct 49 and is filtered by the filter 53. The filtered argon flows into the gas chamber 51. The gas chamber 51 communicates with the inlet bore 43, the exit bore 47 and the heating chamber 33 through the ducts 55 and 57. Admission of air into the furnace 5 is prevented by a first gas stream which flows from the furnace 5 to the outside of the furnace through the bore 43, along the preform P and between the sealing partitions 45 and the preform; another part gas flows through the exit bore 47 and through the outlet ducts 79 to the outside of the furnace 5; a further gas stream flows through the tube 63, condensable reaction products entrained by the gas stream settling on the inner circumference of the tube 63. A substantially uniform slight overpressure is maintained in the interior of the furnace 5.

The coating device 9 shown schematically in Figure 1 is represented in various forms in Figures 4a, 5a and 6a in bottom view and in Figure 4b, 5b and 6b in cross-sectional view. In these Figures identical elements are designated by the same reference numerals.

All three embodiments comprise a coating reservoir 81 provided with a nozzle 83 having a central outlet duct 85 of circular cross-section. The outlet duct 85 adjoins a polygonal nozzle opening, which is bounded by a plurality of segments, which are mounted on the nozzle 83. The cross-section of the nozzle opening gradually decreases and it terminates in a short portion of constant cross-section, which determines the thickness of the coating applied to the optical fibre F. The cross-section of the outlet duct 85 is greater than the cross-section of the adjacent portion of the nozzle opening. The reservoir 81 communicates with a level control, which is designated 87 in Figure 1.

In the embodiment of Figures 4*a* and 4*b*, a square nozzle opening 89 is bounded by four segments 91.

Figures 5*a* and 5*b* show a triangular nozzle opening 93 having three segments 95.

The embodiment of Figures 6*a* and 6*b* is provided with six segments 97, which bound a hexagonal nozzle opening 99.

The segments are adjusted so that the area of

the circle inscribed in that portion of the polyg n of constant cross-section, is approximately 10% greater than the outer diameter of the optical fibre F to be coated. This prevents the fibre F from coming into contact with the segments. The operation and the effect of the polygonal nozzle opening in accordance with the invention has already been described above.

Claims

1. A method of manufacturing an optical fibre, comprising the steps of heating an optical fibre preform in a furnace so as to melt one end of the preform, drawing an optical fibre from the molten end of the platform, withdrawing the optical fibre from the furnace, enveloping the portions of the preform and of the optical fibre which are within the furnace in an inert gas stream, cooling the optical fibre, coating the optical fibre with a layer of a synthetic resin and winding the coated optical fibre onto a reel, wherein the gas stream enveloping the optical fibre passes from the inside of the furnace to the outside of the furnace through a condenser element which surrounds the optical fibre, and wherein an overpressure of the inert gas is maintained inside the furnace with respect to the pressure outside the furnace.

2. A method of manufacturing an optical fibre, comprising the steps of heating an optical fibre preform in a furnace so as to melt one end of the preform, drawing an optical fibre from the molten end of the preform, withdrawing the optical fibre from the furnace, enveloping the portions of the preform and of the optical fibre which are within the furnace in an inert gas stream, cooling the optical fibre, coating the optical fibre with a lacquer, drying the coated optical fibre, and winding the dried coated optical fibre onto a reel, wherein the as stream enveloping the optical fibre passes from the inside of the furnace to the outside of the furnace through a condenser element which surrounds the optical fibre, and wherein an overpressure of the inert gas is maintained inside the furnace with respect to the pressure outside the furnace.

3. A method of manufacturing an optical fibre, substantially as herein described with ref rence t Figures 1 to 3 together with Figures 4*a* and 4*b* or Figures 5*a* and 5*b* or Figures 6*a* and 6*b*.

4. An optical fibre manufactured by a method as claimed in any of Claims 1 to 3.

5. An apparatus suitable for performing a method as claimed in Claim 2, comprising a holder for an optical fibre preform, a furnace, a coating device, a drying device, a drawing device and winding device, the furnace comprising a graphite resistance-element bounding a central heating chamber, the furnace having an inlet bore containing sealing means, an exit bore, and a supply duct for the supply of a gas, characterized in that the furnace is provided with a tubular condenser which is arranged in the exit bore, the centre lines of the condenser and of the heating chamber coincide, one end of the condenser is located inside the heating chamber and the other end is disposed outside the furnace.

6. An apparatus as claimed in Claim 5, characterized in that the condenser is secured in a central bore of a substantially cylindrical support, which support fits into the exit tube of the furnace and is provided with a plurality of outlet ducts, through which ducts gas can pass from inside the furnace to outside the furnace.

7. An apparatus as claimed in Claim 5 or Claim 6, characterized in that the condenser is made of quartz glass.

8. An apparatus as claimed in Claim 5 or Claim 6, characterized in that the condenser is made of platinum.

9. An apparatus as claimed in any of Claims 5 to 8, the coating device comprising a coating reservoir which is provided with a polygonal nozzle opening.

10. An apparatus as claimed in Claim 9, characterized in that the nozzle opening is bounded by a plurality of adjustable segments.

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